AN4085
Application note

EnFilm™ micro-battery EFL700A39 user guide

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Introduction

STMicroelectronics has developed micro battery products (EnFilm™) with reduced thickness and weight.

The characteristics and electrical parameters of the product are detailed in the datasheet.

The EnFilm is easy to use but some design considerations are especially intended to get the maximum performance without damaging the product.

Figure 1. ELF700A39 micro-battery

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1 Handling and assembly of the ELF700A39

Refer to both STMicroelectronics Application Note:

- AN4046 “EnFilmTM micro battery EFL700A39 recommendations for manual assembly on PCB”
- AN4351 “EnFilmTM micro battery EFL700A39 automatic or semi-automatic mounting on PCB”

Those documents are describing all needed information and recommendation for proper handling and assembly on PCB of the ST EnFilm™ micro-battery.

They are available on the “EnFilm: Thin-film batteries” dedicated page of the STMicroelectronics web site (http://www.st.com).

2 Charging the EFL700A39

2.1 Charging voltage

The EFL700A39 can be easily charged from a 4.2 V ±1% constant voltage source with or without current limit. More than 90% of the total capacity is recharged when the charge current falls below 100 µA. For better life duration it is recommended to limit the charge voltage between 4.0 V and 4.2 V.

2.2 Charging current

A constant current charge is possible provided the maximum charge voltage does not exceed 4.2 V.

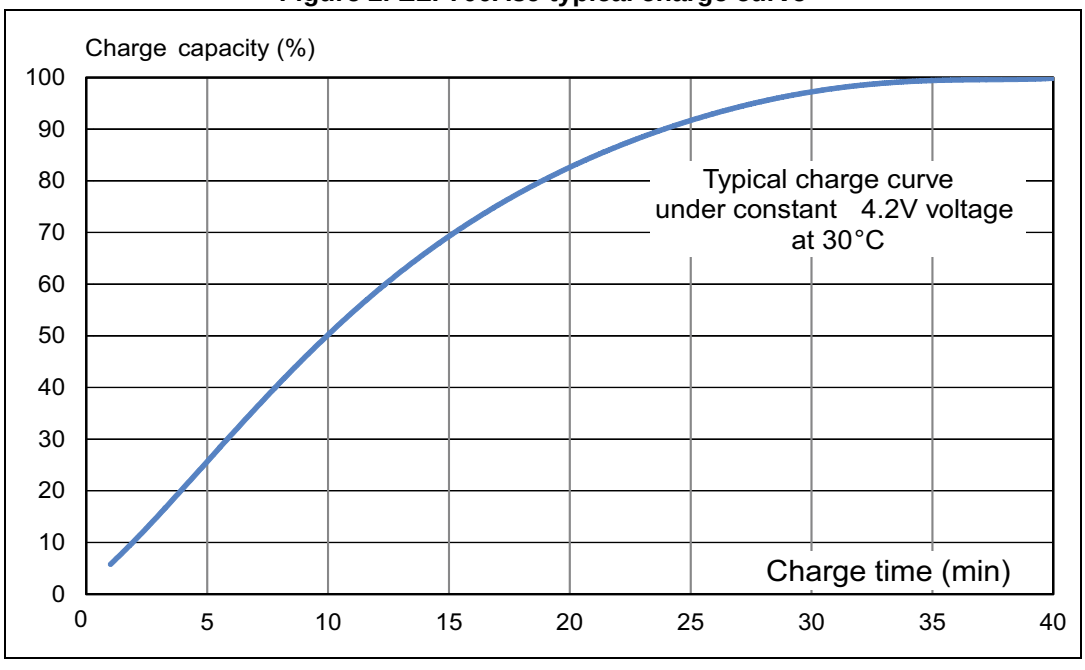
Switch-mode, pulse-mode or linear battery charger devices can be used to secure the maximum battery charge voltage.

2.3 Charging temperature

The higher the ambient temperature is, the faster the charge is but meanwhile the faster is the aging of the EFL700A39.

The *Figure 2* shows the typical curve of the charge capacity versus the charge time duration for a 30 °C ambient temperature. As shown in this figure, the EFL700A39 can be recharged from 0% State-of-Charge (SoC) up to 80% SoC in 20 minutes.

Figure 2. ELF700A39 typical charge curve



3 Discharging the EFL700A39 battery

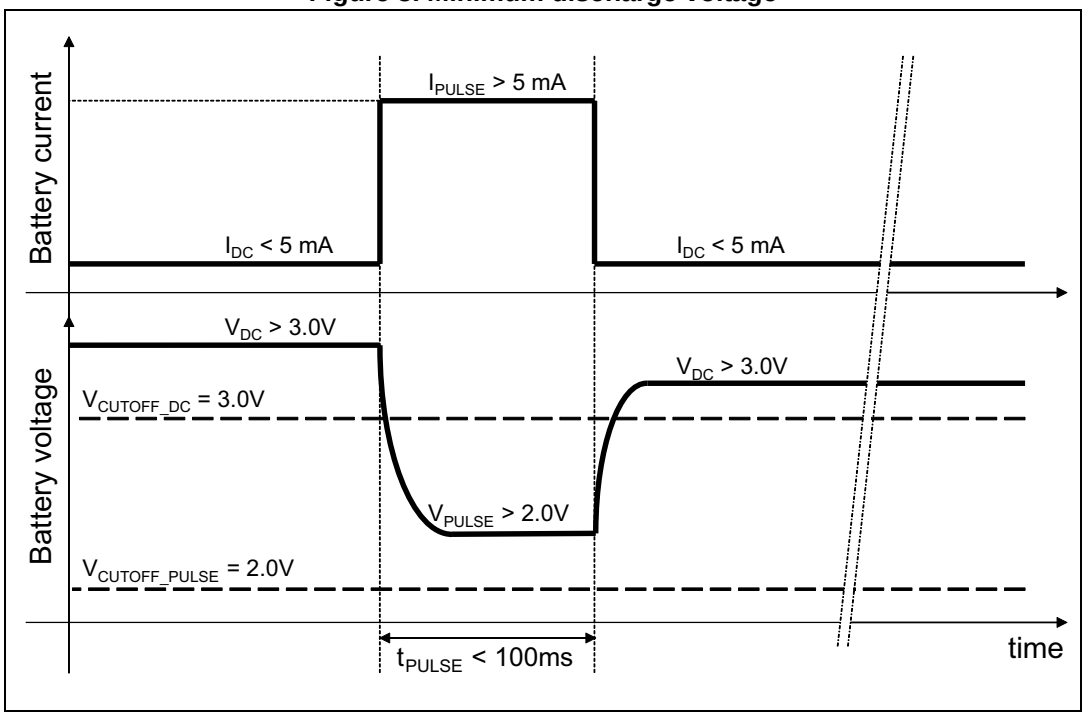
3.1 Minimum discharge voltage

The cut-off voltage is the minimum open-circuit voltage (OCV) across the EnFilm battery.

Under DC conditions, when discharging with a constant current lower than 5 mA, the EFL700A39 cut-off voltage value should never be lower than 3.0 V.

During a pulse current above 5 mA with a pulse duration lower than 100 ms, to compensate the internal ohmic resistance of the EnFilm battery, the EFL700A39 voltage can decay below 3.0 V. Nevertheless, this dynamic voltage drop shall remain above 2.0 V and the battery cut-off voltage shall recover a minimum of 3.0 V after the pulse as shown in the *Figure 3*.

Figure 3. Minimum discharge voltage



Below those minimum cut-off voltage values of 3.0 V under DC conditions and 2.0 V under pulsed conditions, the EnFilm™ battery can be irretrievably damaged.

Battery charger devices integrating an over-discharge protection feature or any custom discrete protection circuit can be used to secure the minimum battery discharge voltage.

3.2 Discharging with continuous current

3.2.1 Discharging characteristics

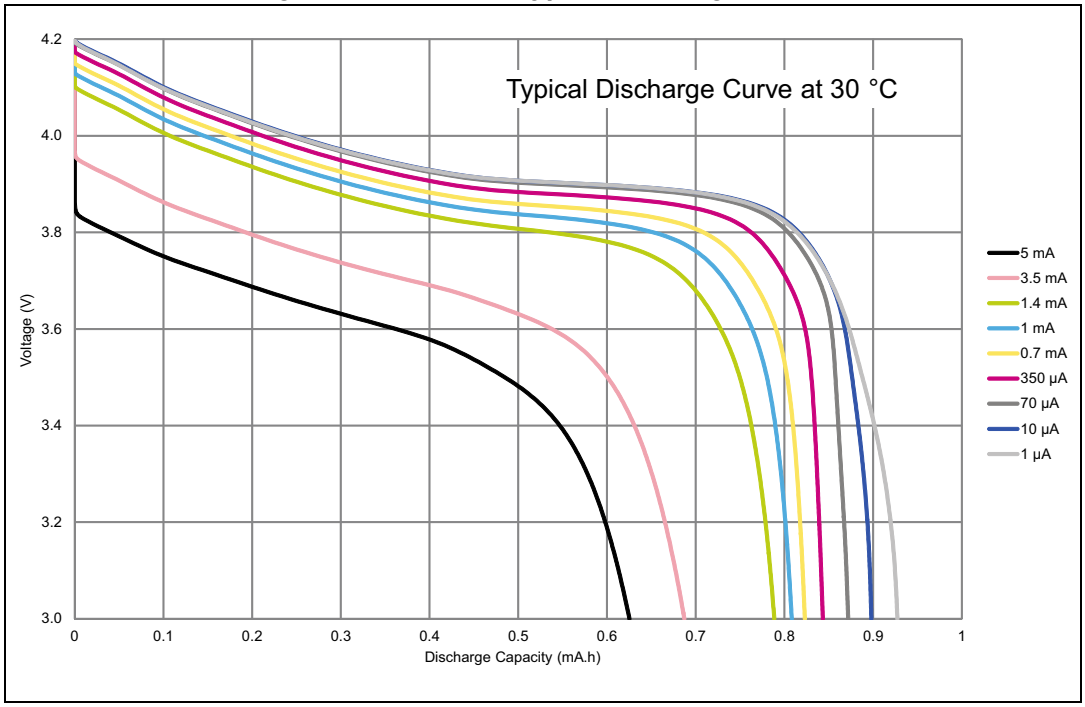
The *Figure 4* shows the typical discharge characteristics of the EFL700A39 battery for different discharge current values from 1 µA up to 5 mA. These battery discharge curves

were performed at 30 °C on 4.2 V fully charged batteries and with a cut-off protection set to 3.0 V.

The initial EnFilm™ micro battery voltage value is 4.2 V for a battery at full charge in open circuit conditions (OCV). When a load is connected, the battery voltage drops to a lower value (the higher is the load current, the higher is the drop voltage), and progressively the battery discharges until the voltage decreases down to the protection cut-off level. In any case, the cut-off voltage must not be fixed below 3.0 V.

Figure 4 curves show that when the discharged capacity increases, the EFL700A39 terminal voltage decreases.

Figure 4. EFL700A39 typical discharge curves



The time between the beginning and the end of a discharge depends on:

- the initial state of charge,
- the discharge current,
- the temperature,
- the minimum operating voltage of the application (cut-off voltage setup).

For example, extracting information from the *Figure 4*, with a constant load current of 1 mA, the charge used by the load starts at 0 mA.h and reaches a maximum of 0.81 mA.h. This means that 1 mA was supplied to the load by the battery during 0.81 h (48 min 36 s) before the 3.0 V cut-off threshold voltage was reached. For a 3.5 mA load current, the cut-off occurs at 0.68 mA.h. The discharge duration can then be calculated as follow: 0.68/3.5 = 0.19 h (11 min 40 s).

3.2.2 EFL700A39 survival time in battery disconnect protection mode

The EFL700A39 open-circuit voltage should not go below 3.0 V in continuous discharge operating conditions.

To prevent deep discharge damage, a battery voltage sense and disconnection circuit - with a threshold voltage higher than 3.0 V - has to be put in place using a battery management IC such as ST SPV1050 device. These ICs must have a very low leakage current drawn from the battery specifically when the battery is disconnected.

The Table 1 provides some example of allowable elapse time in battery disconnect mode for different settings of battery disconnect threshold voltage and different settings of leakage current of the battery management IC. For each case of the Table 1, if the duration of the battery disconnection is longer than these values, the voltage of the EnFilm can drop down below 3.0 V with a risk of unrecoverable damage.

Table 1. EFL700A39 elapsed time from battery disconnect until 3.0 V maximum discharge level for different leakage current at 30 °C temperature

Battery disconnect threshold voltage	IC leakage current in battery disconnect mode		
	1nA	10nA	100nA
3.80V	3 years	9 months	36 days
3.60V	17 months	4 months	17 days
3.40V	8 months	2 months	8 days
3.20V	2 months	19 days	2 days

For example, referring to the product datasheet of the ST SPV1050 IC, the leakage is specified below 1 nA as shown in the *Table 2* and the cut-off voltage is adjustable from 2.1 V up to 3.6 V (“2.1 V TO 3.6 V trimmable battery under voltage protection level”).

Table 2. ST SPV1050 datasheet extract for leakage current in battery disconnect mode

Sumbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
Static current consumption						
I_{SD}	Shutdown current	Shut down mode: Before first startup or $\overline{BATT_CONN}$ high T_{AMB} < 60 °C			1	nA

Choosing a 3.60 V cut-off voltage setup ensures, according to the *Table 1*, 17 months of EFL700A39 micro-battery survival time. It means that once the battery is disconnected, a source of energy like a harvester has to charge the EFL700A39 before 17 months (1.4 years).

3.2.3 Recommended maximum load current overtemperature

The *Figure 5* provides the characteristics of the EFL700A39 internal resistance on the battery operating temperature range. The battery internal resistance is decreasing when the temperature is rising.

The *Figure 6* shows the maximum load current available over the ambient temperature for safe operating cut-off voltages of 3.0V (minimum), 3.2 V, 3. 4V and 3.6 V.

For example, at +30 °C ambient temperature and considering a 3.2 V cut-off voltage, a maximum DC load current of 5.0 mA can be drawn. This maximum continuous current capability is decreasing to 1.8 mA if the minimum ambient temperature of the application is 10 °C.

If the EFL700A39 is protected by a battery management IC with a cut-off voltage set at 3.6 V, then the maximum load current will be 2.9 mA at 30 °C (0.8 mA at 10 °C) and the maximum 5 mA DC current capability will be achieved for a temperature higher than 40 °C.

Figure 5. EFL700A39 internal resistance variation vs. temperature

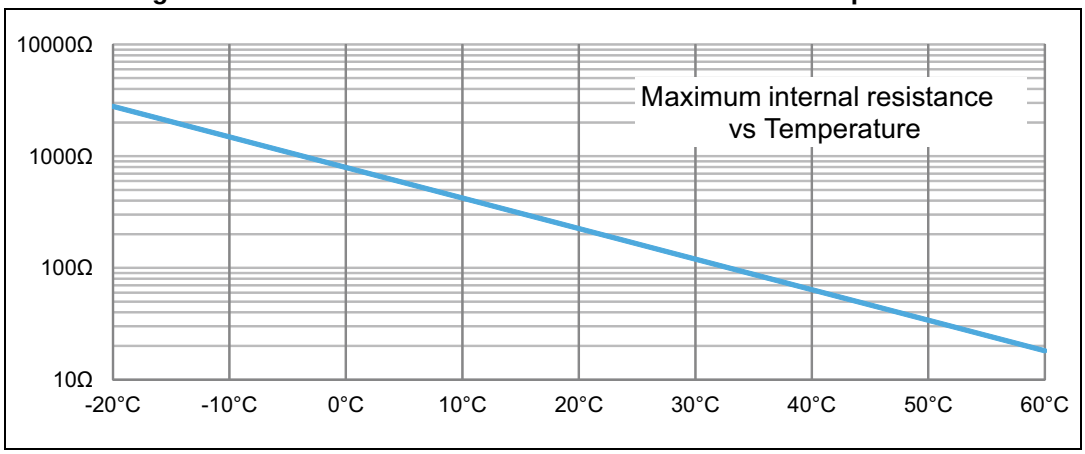
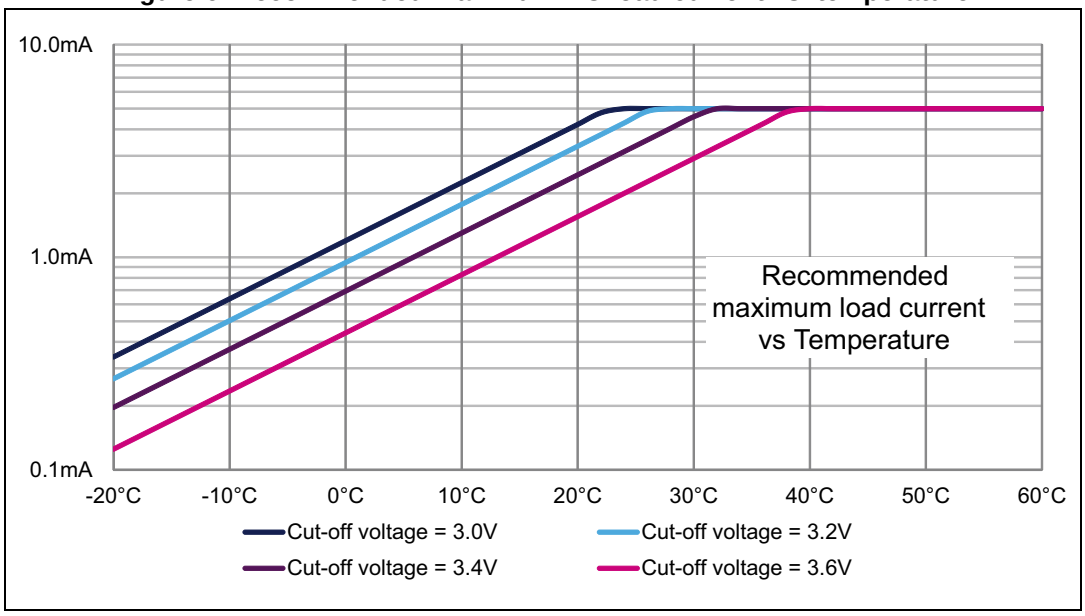


Figure 6. Recommended maximum DC load current vs. temperature



3.3 Discharging with pulsed current

Some application may exhibit pulsed load current consumption with low steady state current and high pulsed current alternatively. This type of load is typical of a wireless sensor network where current pulses are generated by RF transmissions.

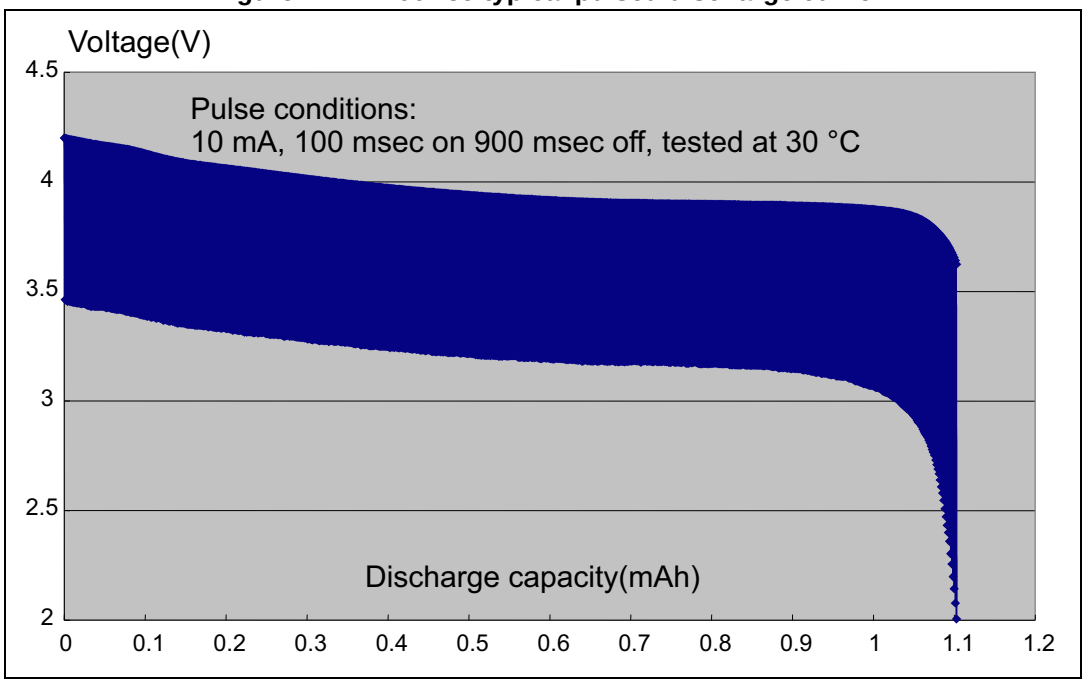
3.3.1 Using EFL700A39 in stand-alone configuration

The EFL700A39 micro battery is able to withstand pulsed current discharges.

The *Figure 7* shows a typical discharge curve for pulsed current discharge application with following conditions applied on a stand-alone EFL700A39 battery:

- "ON" state: t_{ON} = 100 ms, I_{ON} = 10 mA, cut-off voltage during pulse = 2.0 V
- "OFF" state: t_{OFF} = 900 ms, I_{OFF} = 0 (no load current)
- T_{amb}= 30 °C

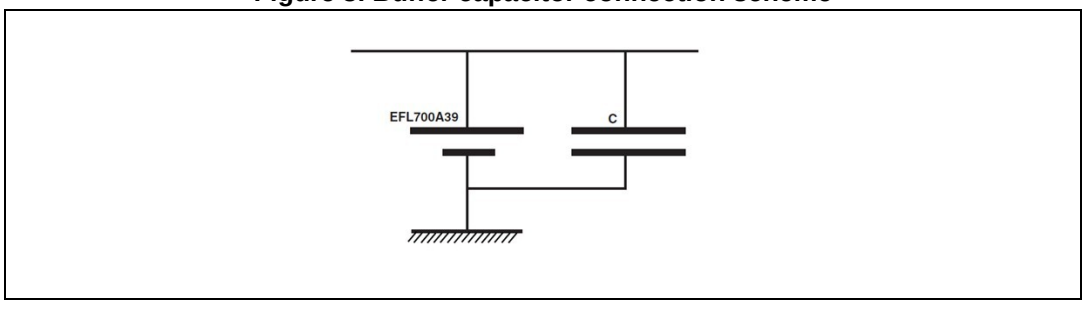
Figure 7. EFL700A39 typical pulsed discharge curve



3.3.2 Using a buffer capacitor to increase the pulse current

For applications in which pulsed current levels are higher than 10 mA and/or in which operating temperature are lower than 30 °C, it is required to add a buffer capacitor in parallel with the EFL700A39 as shown in the *Figure 8*.

Figure 8. Buffer capacitor connection scheme



The buffer capacitor aims are to keep the battery in a safe operating area, to stabilize the output voltage supplied to the application and also to avoid triggering the battery voltage sense and disconnection circuit. In order to choose the most adapted buffer capacitor, we

recommend to refer to the *Figure 9* and the *Figure 10* which show various buffer capacitor choices depending on pulsed current characteristics.

As an example, if the application peak pulse current is 20 mA during 4 ms then the buffer capacitor minimum value over the application temperature range should be:

- 100 µF if the minimum allowed system supply voltage is 3.0 V
- 320 µF if the minimum allowed system supply voltage is 3.6 V

The *Figure 11* provides a suggestion of technology for the buffer capacitor depending of the pulse current characteristics.

In order to ensure the buffer capacitor is effectively recharged by the EFL700A39 battery between two pulses, each pulse must be followed by a steady state. This constraint steps the transmit interval for the load.

The minimum transmit interval can be easily calculated from the battery resistance (R) and the value of the buffer capacitance (C) calculated previously. First, it is needed to pick the battery resistance (R) at the minimum application temperature in the Figure 6. Then, the minimum transmit interval between 2 pulses is equal to 3*R*C.

Figure 9. Buffer capacitor sizing versus pulse duration and peak pulse current for a minimum 3.0 V supply voltage during the pulse

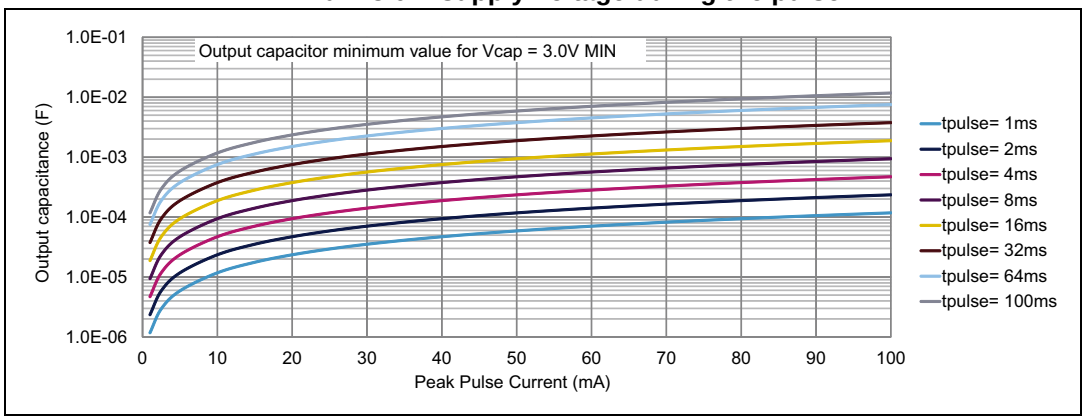


Figure 10. Buffer capacitor sizing versus pulse duration and peak pulse current for a minimum 3.6 V supply voltage during the pulse

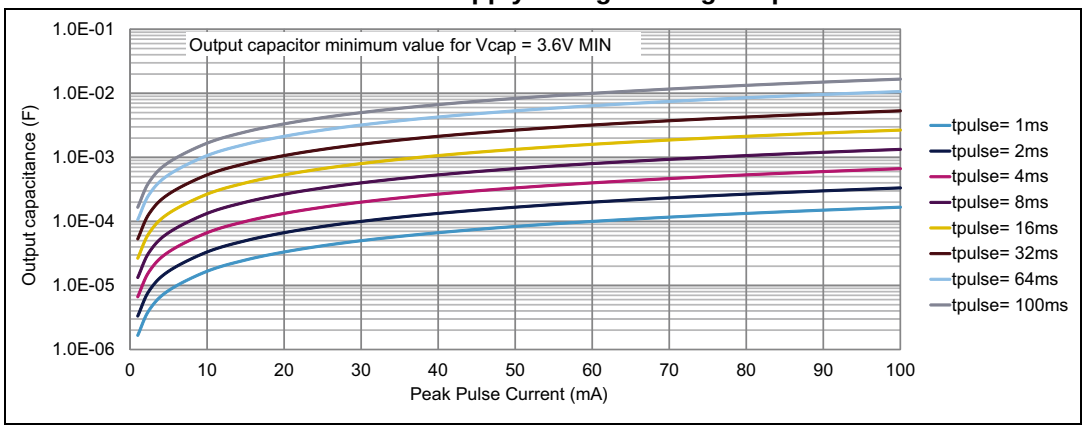
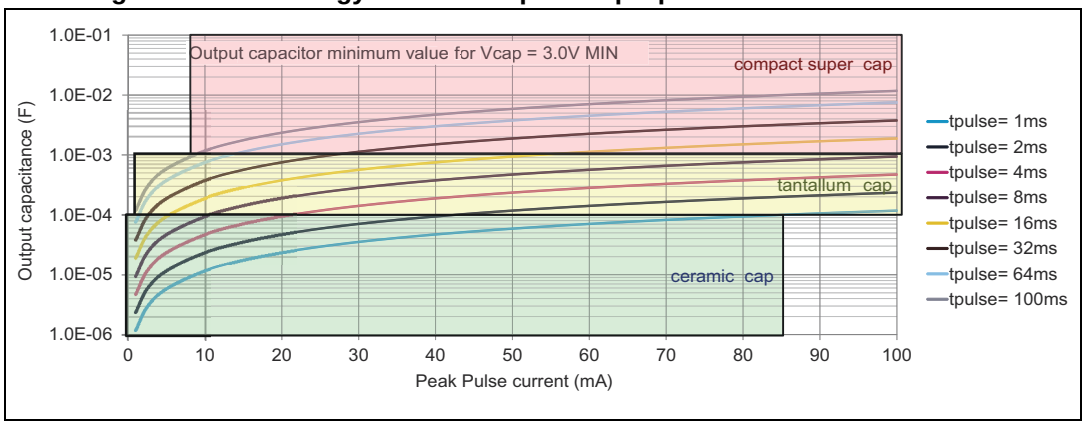


Figure 11. Technology of buffer capacitor proposed versus current need



4 Available power management IC’s and tools

4.1 STMicroelectronics SPV1050 IC’s

The SPV1050 is an ultra-low-power energy harvester and battery charger with embedded MPPT and LDOs. Its main features are:

- Thermoelectric generators and PV modules energy harvester
- High efficiency for all harvesting sources, PV cells and TEG.
- Up to 70 mA maximum battery current
- Fully integrated buck-boost DC-DC converter 2.5 V to 5.3 V
- Trimmable battery charge voltage level (± 1% accuracy) 2.1 V to 3.6 V
- Trimmable battery discharge voltage level (± 1% accuracy)
- Two fully independent LDOs (1.8 V and 3.3 V output)
- Enable/disable LDO control pins
- Battery disconnect function for battery protection
- Battery connected and ongoing charge logic open drain indication pins
- Programmable MPPT by external resistors

The product datasheet and additional information are available on STMicroelectronics web site (http://www.st.com).

4.2 STMicroelectronics EFL700A39 evaluation boards

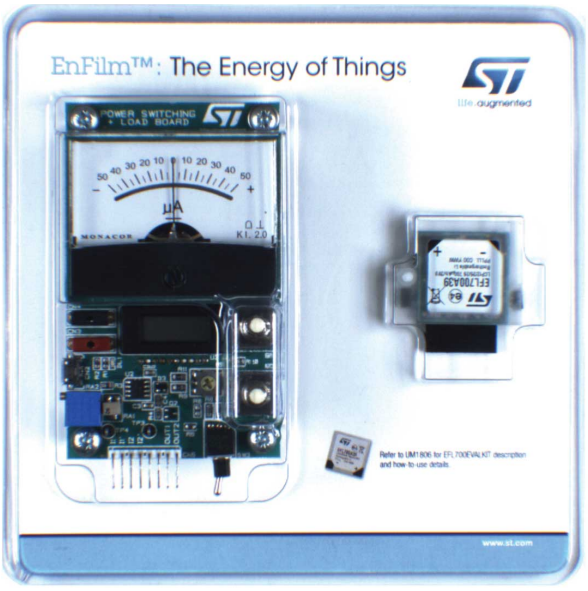
Two boards have been developed for training and supporting the design of the solid state thin film battery EnFilm™ EFL700A39.

The Evaluation kit (Order Number: EFL700EVALKIT) allows to discover the operation of the EFL700A39 and to monitor the voltage and the dynamic charge /discharge current in real use-case condition.

The power management board (order number: EFL700PMB) is rather a design-in board including all the necessary power management circuit around the EFL700A39 and can be directly connected and used in the application for a fast evaluation.

Figure 12. EFL700A39 power management board (EFL700PMB)

Figure 13. EFL700A39 evaluation kit (EFL700EVALKIT)



The *Figure 12* shows the EFL700PMB board. Its features are:

- Management of the charge and the voltage regulation of the EFL700A39
- Battery protection against deep discharge
- Recharge possibility through an external energy harvesting
- Includes a super capacitor to sustain high pulsed discharge current

The *Figure 13* shows the EFL700EVALKIT which is including the EFL700PMB board and a load board. Its features are:

- Includes an analogical ammeter and a digital voltmeter to monitor:
  - the current delivered by the source
  - the current going through the EFL700A39 battery
  - the battery voltage
- Includes a pulsed load emulator with the possibility to adjust the pulsed load cyclic ratio.

For additional information, refer to the STMicroelectronics UM1806 user manual "EFL700A39 evaluation board kits and design-in board user guide".

This document is available on the "EnFilm: Thin-film batteries" dedicated page of the STMicroelectronics web site (http://www.st.com).

5 Revision history

Table 3. Document revision history

Date	Revision	Changes
11-Jan-2012	1	Initial release.
12-Feb-2015	2	Comprehensive content revision.

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